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BULLETIN OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

Vol. V LANCASTER, PA., NOVEMBER, 1914 No. 3

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BULLETIN

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EDITORIAL.

The Joint Committee on Engineering Education.—One of the most important pieces of work which is being done by this Society is through its membership on the Joint Committee on Engineering Education, which is noted in the report of that

Committee. This Committee was organized at the Cleveland meeting in 1907. The members of this Committee from this Society are Prof. C. L. Crandall, Prof. D. C. Jackson, and Dean Gardner C. Anthony. The Committee has held numerous meetings and during the past year, in conjunction with the Carnegie Foundation for the Advancement of Teaching, selected Dr. C. R. Mann, associate professor of physics at the University of Chicago, a well known physicist and a man, who for many years has been prominent in the campaign for the improvement in the teaching of physics, to conduct an investigation of engineering education. His breadth of training, and his valuable knowledge of the fundamentals of teaching make him an exceedingly good agent for this work. The members of this Society and all teachers of engineering education will be interested in reading his address which appeared in the October number of the BULLETIN. Dr. Mann is assured of the closest cooperation in his work by all members of the Society.

Printed Engineering Resources.—Professor Telleen in his admirable article on "Printed Engineering Resources" appearing in this number of the BULLETIN, has made a very material contribution to engineering education. Many teachers of engineering will be glad to learn of the printed resources available and also of the fact that these resources are available not only to the residents where the libraries are located, but to non-residents as well.

The Standard Pound Force.—The distinction between "standard" and "local" units of force, as proposed by Professor Huntington in the BULLETIN for June, 1913, has been formally accepted by the U. S. Bureau of Standards; see the revised edition of their Circular No. 34, on "The Relation of the Horsepower to the Kilowatt" (issued August 1, 1914), p. 7, The standard pound force is now defined as the force exerted by gravity on a standard pound body in the standard locality, that is, in any locality where g has the standard value 980.665 cm./sec.^{2}. It is therefore no longer necessary to think of the

"pound force" as a "variable unit," the standard pound force being now just as "absolute" a unit as the standard meter.

REASONS FOR JOINING THE S. P. E. E.

The four following reasons for becoming a member of the Society for the Promotion of Engineering Education have been modified from an excellent editorial by H. D. James, appearing in the Proceedings of the A. I. E. E., VXXXIII, page 282:

1. One should be a member of the national society that represents his profession. The first estimate of a teacher of engineering is often made by referring to our membership list, the high character of the men whose names are found there gives real prestige to the teacher who is a member.

2. Every live teacher should have the technical information on teaching made available through the PROCEEDINGS and the BULLETIN of the Society for the Promotion of Engineering Education.

3. The up-to-date teacher, as never before, must meet with other teachers to discuss the live problems of his profession.

4. You should do something for your own profession. The Society for the Promotion of Engineering Education is doing a great work for engineering education, and every man in that profession should do his part.

PERSONALS.

President Marston spent Monday, November 9, with the secretary, going over the work of the Society and making plans for next year.

R. M. Hughes, president of the Miami University, Dean Potter of the Kansas State Agricultural College and Dean Scrugham of the University of Nevada, visited the secretary's office recently.

Professor L. H. Harris, assistant secretary, spent November 12 in New York in consultation with the Treasurer, Mr.

W. O. Wiley, and Vice-President, Mr. H. H. Norris, in regard to the work of the Society.

APPLICANTS FOR MEMBERSHIP.

BROWN, S. LEROY, Adjunct Professor of Physics, University of Texas, Austin, Tex.

DOLAND, J. J., Instructor in Engineering Mathematics, University of Colorado, Boulder, Col.

ECKEL, C. L., Instructor in Civil Engineering, University of Colorado, Boulder, Col.

MORRILL, J. B., Assistant Professor of Engineering Mathematics, University of Colorado, Boulder, Col.

WIRT, F. A., Instructor in Farm Mechanics, Kansas State Agricultural College, Manhattan, Kan.

ADELSPERGER, ROLLAND, Professor of Architecture and Architectural Engineering, A. & M. College of Texas, College Station, Tex.

CRAWFORD, D. F., General Superintendent of Motive Power, Pennsylvania Lines, and Director of Railway Mechanical Engineering, University of Pittsburgh, Pittsburgh, Pa.

DYCHE, H. E., Assistant Professor of Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa.

FREEMAN, P. J., Instructor in Applied Mechanics, Kansas State Agricultural College, Manhattan, Kan.

MCCANDLESS, L. C., Instructor in Civil Engineering, University of Pittsburgh, Pittsburgh, Pa.

MCCORMICK, S. B., Chancellor, University of Pittsburgh, Pittsburgh, Pa.

MCNAIR, G. B., Instructor in Electrical Engineering, Kansas State Agricultural College, Manhattan, Kan.

MORRISON, R. L., Professor of Highway Engineering, A. & M. College of Texas, College Station, Tex.

POWERS, W. P., Instructor in Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa.

SHUBB, J. C., Assistant Instructor in Steam and Gas Engineering, Kansas State Agricultural College, Manhattan, Kan.

SMITH, S. A., Assistant in Department of Architecture and Drawing, Kansas State Agricultural College, Manhattan, Kan.

WAITE, E. B., Dean and Head Consulting Department, American School of Correspondence, Chicago, Ill.

WING, S. R., Acting Professor of Mechanical and Electrical Engineering, Pennsylvania College, Gettysburg, Pa.

COLLEGE NOTES.

Case School of Applied Science.—The following appointments have been made: R. H. Danforth, professor of mechanics and hydraulics; H. D. Allen, assistant professor of German and acting head of the department; Instructors: J. E. Boethius, German and Spanish; O. P. Schinnerer, German; K. O. Thompson, English; R. O. Jackson, mechanical engineering; B. C. Boer, drawing and descriptive geometry; M. G. Edwards, geology and mineralogy; T. D. Bains, Jr., mining engineering; and A. H. Day, director of the gymnasium. The salaries of full professors have been raised to $3,500. A 10-kw transformer of 20,000-volt secondary circuit for high frequency work, together with condensers, Tesla coils, etc.; a 5-kw transformer for insulating testing; a Macbeth portable luminometer, and two precision wattmeters of the astatic type for standardizing laboratory have been added to the electrical department. One Riche adiabatic vacuum jacketed calorimeter; a two valve bomb for determining heat values of fuels; 1 Gran-annular high temperature electric furnace; 1 Siemens-Halske platinum iridium pyrometer; 1 titration voltameter; 1 gas voltameter; and electric furnaces and electric drying ovens have been added to the chemical department. The physics department has installed a wireless receiving apparatus for time signals; very sensitive balance for radioactivity work; new form of Brun-Viga calculating machine; harmonic synthesizer—32 components—designed by Professor Miller and built in the Case shops. This machine has unusual range and can be set and operated with great ease. While especially constructed for analysis of sound waves it is adapted to the study of curves in general and can be used for mathematical, electrical, or meteorological work. A weather bureau station with complete equipment of recording instruments has also been installed in this department. A 75-kw Westinghouse steam turbine generator unit, and small apparatus consisting of Orsat gas analysis apparatus, recording pressure gauges, etc., have been added to the mechanical de-

partment. A Reichert micro-metallograph, several metallographic microscopes, and several electric furnaces are additions to the mining department.

Drexel Institute of Arts, Science and Industry.*—The faculty changes this year are Hollis Godfrey, Sc.D., F.R.G.S., president; Arthur J. Rowland, Sc.D., dean; Henry V. Gummere, M.A., director of evening classes. Additional laboratories have been added to the domestic science and arts, and the chemical laboratory has been enlarged.

Harvard University.—Mr. S. S. Yates, instructor in civil engineering, has resigned to engage in professional practice. During the coming year, in view of the amalgamation which has taken place between the School of Applied Science and the Massachusetts Institute of Technology, Prof. Swain will be assisted in his work at Harvard by Prof. James M. Barker of the M. I. T. During the coming year there will be some coördination between the courses at Harvard and those at M. I. T. and Prof. Swain will give some instruction at the latter institution.

University of Idaho.—In February of last year when Prof. R. S. McCaffery accepted a call to the chair of metallurgy in the University of Wisconsin, Prof. D. C. Livingston was made acting head of the department of mining and metallurgy. Prof. G. L. Larson has been granted a year's leave of absence and is at the University of Wisconsin where he has a research fellowship, and Mr. C. E. Coolidge, Yale '95, has taken his place with the title of associate professor. Mr. A. M. Winslow, Brown Univ, '03, M. I. T., '06, comes to the university as assistant professor of civil engineering. Mr. G. E. Purmort is junior instructor in civil engineering. Mr. L. W. Currier has been appointed instructor in the department of mining and metallurgy. Mr. J. E. Black has been appointed instructor in machine shop practice and wood working, to fill the vacancy caused by the accidental drowning of Mr. George Hall while crossing the Snake river.

* Corrected.

University of Illinois.*—Chas. A. Ellis, assistant professor of civil engineering; Lero A. Wilson, assistant in engineering experiment station in the department of mechanical engineering; Wm. H. Hyslop, assistant in physics; C. F. Hill, and P. L. Bayley, as part-time assistants in physics; H. F. Gonnerman, transferred to the engineering experiment station as first assistant in the department of theoretical and applied mechanics; instructors W. D. Foster, and R. S. Fanning, in architectural design; W. M. Stanton, architecture; W. S. Wolfe, architectural engineering; J. W. Davis, electrical engineering; H. S. McDewell and E. Frank, mechanical engineering; A. C. Callen, mining engineering; W. J. Putnam, theoretical and applied mechanics; J. O. Draffin, as research fellow in the engineering experiment station in the department of theoretical and applied mechanics; W. A. Gatward, research fellow in the engineering experiment station in the department of electrical engineering; T. E. Laying, research fellow in the engineering experiment station in the department of chemistry; L. C. Lichty, research fellow in the engineering station in the department of mechanical engineering; Wm. Penn Lukens, research fellow in the engineering station in the department of mechanical engineering; E. G. Young, research fellow in the engineering station in the department of railway engineering.

University of Kansas.—Prof. B. J. Dalton, of the department of railway civil engineering, has left the institution on leave of absence to take up work with the Interstate Commerce Commission on the valuation of property of common carriers. He holds the position of assistant district engineer in the 4th district with office at Kansas city.—To fill the vacancy created by the departure of Professor Dalton, the university secured Prof. C. C. Williams who had been at the head of railway civil engineering at the University of Colorado for several years.—Dean F. O. Marvin, who has been at the head of the school of engineering from the time of its organization

* Corrected.

until his failure of health compelled him to withdraw from active work in 1913, has recently been retired under the provisions of the Carnegie Foundation. During the past year he has been connected with the school in the capacity of advisory dean, which connection will probably be maintained, possibly with an emeritus title.—The first work offered in engineering at the university, which was in the late 70's, was under the charge of Dean Marvin. From the small beginnings at that time through the various stages of growth as the work was provided for, first as a department of the college of liberal arts and sciences, and since 1891 as a distinct school of engineering, his has been the guiding hand which has shaped the policy throughout.

Kansas State Agricultural College.—A. A. Potter, professor of steam and gas engineering at the College, was made dean of the Engineering Division and Director of the Engineering Experiment Station. Mr. Potter expects to retain his professorship in steam and gas engineering. Clarence E. Reid, professor of electrical engineering at the Mississippi A. & M. College, was elected professor of electrical engineering vice Professor B. F. Eyer, who entered practical engineering work. S. L. Simmering, of the Pennsylvania State College, was elected instructor in steam and gas engineering. J. C. Shutt, of Highland Park College, was elected assistant in steam and gas engineering.

Massachusetts Institute of Technology.—The first structure that the M. I. T. has caused to be constructed for its own uses on its site in Cambridge is the new aerodynamic laboratory. The building is finished and the apparatus is in process of installation. This together with the fact that M. I. T. has already instituted courses in the study of this science makes it the first college in the land to be fitted to prepare students for what must in the future be an exceedingly important line of development. Beginning with this year the institute offers a graduate course leading to the degree of master of science, which is open to graduates of the institute in mechanical

engineering, electrical engineering, and naval architecture, and to graduates of other colleges whose preparation is equivalent to the work required for the bachelor's degree in one of these courses.

An important contribution to scientific knowledge is that just published by the Society of Arts, which is one of the divisions of the M. I. T.

The institute has recognized the need of systematic observation of volcanoes and for the purpose has established in the Hawaiian Islands an observatory, where with most recent methods and equipment the facts that the crater has to offer are to be collected. The work owes its initiative to the interest and activity of Prof. T. A. Jaggar, of the Geological Department, who has been named director of the Hawaiian Volcano Observatory.

With the close of the spring term, Prof. R. H. Richards retired from active work of teaching which he has followed for forty-six years. He is made professor emeritus and receives the benefits of the Carnegie Foundation. Ten thousand alumni scattered all over the country will be interested in the fact that "Burrie" is retiring at the end of the school year.

University of North Dakota.—During the past year Dean Calvin H. Crouch, having been granted a year's leave of absence, spent six and one half months with the Allis-Chalmers Manufacturing Co., of Milwaukee, six weeks visiting engineering schools and the remainder of the time with the Standard Steel Car Co. of Pittsburgh. This year, Prof. A. J. Becker has been granted a leave of absence for the same length of time.

Ohio Wesleyan University.—Mr. Pearl Whitfield Durkee, B.A., Acadia University of Nova Scotia, 1903, and B.S., in electrical engineering, McGill University, Montreal, 1906, was made assistant professor of physics and mechanical drawing.

Stevens Institute of Technology.—The freshman class, the largest in the history of Stevens, numbers 178; this is an increase of 81 per cent. over last year's enrollment. Most of the

extraordinary increase is due to the adoption of the new scheme of admitting students on certificates from the principals of approved high schools with four year courses. Ninety-one schools from thirteen states are represented by the matriculants. Mr. C. L. Coggins, B.S., instructor in physics, has resigned to accept an assistant professorship at the Rhode Island State College. Mr. Lawrence C. F. Horle, M.E., has been appointed assistant in physics. Stevens Institute has recently been promised bequests of $250,000 from the Rockefeller Foundation—this being the first donation to a technical school ever made by the foundation—$250,000 from Mr. Andrew Carnegie, $50,000 from an anonymous friend, and $10,000 from Mr. W. H. Childs, on condition that it raises an additional $800,000 within a year. Of this sum $60,000 was subscribed almost immediately. The classes of 1913 and 1914 have given, respectively, $3,500 and $1,050 toward the gymnasium fund. At the commencement exercises all of the five students, Messrs. Albers, Bayer, Hohman, Sortore and Van Vechten who received money prizes amounting to $170, returned them for the same purpose.

Robert College, Constantinople, Turkey.—On account of the war situation, there was a question as to whether or not the school would open, but it did and the attendance is remarkably good, being more than 80 per cent. of last year. The college has been given recently $50,000 for use in extending the engineering laboratories, which when completed will aggregate 35,200 square feet of floor space. The college is expending $20,000 for laboratory equipment such as a 50 H.P. Diesel engine, an alternating current generator, a rotary converter and an accumulator. Mr. F. L. Hitchcock, of Cornell, has been appointed instructor in civil engineering, Mr. J. B. Johnson, of Colorado School of Mines, instructor in chemistry and mining engineering, and Mr. L. B. Breed-Love, of the University of Illinois, as chief operating engineer and instructor in the power laboratory.

South Dakota State College.—The engineering society is carrying out a very complete program this winter. Monthly

meetings are being held and the details of these were arranged at the beginning of the year. A neat booklet in convenient pocket size contains full information. The society has held an exhibit in which the laboratory apparatus of the college was shown in operation.

University of Utah.—The following appointments have been made: H. P. Barrows, assistant professor of agricultural education; T. A. Beal, assistant professor of economics and sociology; L. L. Butler, B.A., M.A., assistant professor of English; F. W. Skirrow, assistant professor of chemistry; H. L. Marshall, assistant professor of physical education and N. H. Norgren, athletic coach.

Washington University, St. Louis.—Registration in the University as a whole shows a decided increase. Professor Ferrand, Professor Abella, and Mr. M. Faure were called home to France to join their regiments. Mr. M. Kirschstein, M.A., E.E., has been appointed instructor in electrical engineering to succeed Dr. W. B. Kouwenhoven, who has accepted an assistant professorship at Johns Hopkins University.

West Virginia University.—Mr. Robert S. Gatherum has been appointed assistant professor of mining. Mr. Gatherum's duties will keep him constantly in the mining fields of the State. A part of his work will be to organize classes for mining instruction at each place visited, these to be then placed in charge of some local man well qualified for the work. The courses of instruction and instructional papers will be such as are recommended by the department of mining at the University and will be chosen for their special fitness to the conditions.

University of Wisconsin.—The following appointments have been made: Ralph Keffer, instructor and A. W. Larson, assistant instructor in mathematics; L. W. Butler, C. S. Cragoe, N. C. Eyring, M. Frehafer, F. Gray, H. C. Harvey, W. H. Hoover, A. F. Kibler, M. H. Petersen, H. TeSelle, and E. Anderson assistants in physics; L. J. Marquardt, instructor in drawing and descriptive geometry; J. D. MacLean, in-

structor in machine design; L. B. McMillan, instructor in steam and gas engineering. The five year advanced course in engineering has been discontinued. The resignations of Juan D. Diaz, draftsman, and D. C. Faber, assistant professor of electrical engineering, have been accepted. C. C. Winn and H. E. Kranz have been appointed instructors and L. C. Straub draftsman.

PROFESSOR CHARLES LABAN ADAMS

1856–1914.

Charles Laban Adams was born November 26, 1856, in New York City. His early education was in the public schools, and later in the Massachusetts Normal Art School. He also studied painting at the Art Museum and with A. Oudinot, a French landscape painter and pupil of Corot.

Professor Adams had been a teacher of drawing at the Massachusetts Institute of Technology since 1881. In 1881–82 he took a special course, in his spare time, in the Mechanical Engineering Department. This work associated him with the class of 1884, M. I. T. In 1885 he developed a course in lettering and a course in freehand drawing for the architectural department, the latter course including the study of the human figure as a part of decorative design. In 1903 he was appointed assistant professor of drawing and descriptive geometry. In 1904 he was appointed associate professor; and in 1912 professor of drawing and descriptive geometry.

The books published by Professor Adams are as follows: "Letter Drawing Plates," published in 1893. In 1905 he published a book on "Mechanical Drawing, Technique and Working Methods for Technical Students." In 1907 he published "Notes on Descriptive Geometry."

Professor Adams always kept up his interest in painting, and exhibited at the Art Clubs in New York, Philadelphia and

Boston. He was a member of the Boston Art Club and the Technology Clubs of Boston and New York. For many years in addition to his teaching at the institute Professor Adams was superintendent of the Roxbury Free Evening Drawing School. He became a member of the society for the Promotion of Engineering Education in 1904.

In June, 1914, Professor Adams started on a trip to Italy, Germany and France, intending to return by way of Liverpool. While taking a journey down the Rhine he had an attack of appendicitis. An operation was performed at Boerhaave Kliniek in Amsterdam, but a change for the worse came soon after this and he died September 16. He is survived by a widow and three children.

Professor Adams was possessed of rare executive ability and the capacity for organizing the instruction for large classes. During the last ten years he has arranged and superintended the work in freehand, mechanical drawing and descriptive geometry for four hundred first year students at the Massachusetts Institute of Technology, at the same time directing the more advanced work in figure drawing in the architectural department of the institute.

BOOKS RECEIVED.

Machine Drawing and Design. By D. A. Low. Published by Longmans, Green & Co. Price 75 cents.

Preliminary Machine Drawing Course. By C. E. Handy. Published by Longmans, Green & Co. Price, 30 cents.

Engineering Workshop Drawing. By Henry J. Spooner. Published by Longmans, Green & Co. Price, 50 cents.

Mathematics for Agricultural Students. By Henry C. Wolff. Published by McGraw-Hill Book Co. Price, $1.50.

Elementary Mathematical Analysis. By Charles S. Slichter. Published by McGraw-Hill Book Co. Price, $2.50.

Geological and Topographical Maps, Their Interpretations and Use. By ARTHUR R. DWERRYHOUSE. Published by Edward Arnold, London. Price, $1.25.

Chemical German. By FRANCIS S. PHILLIPS. Published by The Chemical Publishing Co. Price, $2.00.

Scientific Management. By C. BERTRAND THOMPSON. Published by Harvard University Press. Price, $4.00.

American Society for Testing Materials, Year Book.

BOOK REVIEW.

Chemical German. By FRANCIS C. PHILLIPS, Professor of Chemistry in the University of Pittsburgh. The Chemical Publishing Company, Easton, Pa. 1913. Pp. xi + 241. Price, $2.00.

This systematic work, which is " intended for students who have had at least a year of German and who have mastered the elements of chemistry," differs, both in plan and scope, from the several books which have appeared on " Scientific German." It gives the student an excellent opportunity to familiarize himself with the German language of chemistry, a working knowledge of which is so essential to the chemist. The reading exercises have been carefully selected and are arranged with splendid judgment. A feature of the book is the comprehensive technical vocabulary with which it concludes.

Already this book is fulfilling its purpose in a number of universities. It is a most valuable contribution to chemical pedagogy by a teacher of forty years' experience.

W. A. HAMOR.

REPORT OF THE JOINT COMMITTEE ON ENGINEERING EDUCATION.

The original resolutions under which the Joint Committee on Engineering Education was appointed were passed at the Cleveland meeting in 1907. They are as follows:

WHEREAS, It is desirable to make a comprehensive study of the objects and the utilities and the correct ideals of engineering education; therefore be it

Resolved, That the Society for the Promotion of Engineering Education hereby invite the respective governing boards of The American Society of Civil Engineers, The American Society of Mechanical Engineers, The American Institute of Electrical Engineers and The American Chemical Society, each to appoint two members to become delegates composing part of a joint committee on engineering education, which committee shall consist of the said two members appointed from each of the aforesaid societies, or the delegates from such societies as accept this invitation and appoint their respective delegates, and three members appointed as delegates by the Society for the Promotion of Engineering Education; and in pursuance thereof be it further

Resolved, That the council of the Society for the Promotion of Engineering Education is hereby directed to appoint three members as delegates to the membership of the said joint committee on engineering education; and be it further

Resolved, That the duty of the said joint committee shall be to examine into all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, and the proper relations of engineering schools to secondary industrial schools, or foremen's schools; and to formulate a report or reports upon the appropriate scope of engineering education and the degree of cooperation and unity that may be advantageously arranged between the various engineering schools."

The resolutions further state that the joint committee is

requested to make a report of progress to this society within a year, and to make its final report to this society within two years.

At the Detroit meeting in 1908 a resolution was passed authorizing this committee to invite the Carnegie Foundation for the Advancement of Teaching and the General Education Board to appoint delegates.

During the intervening year the time was taken up in organizing the joint committee. This was a difficult matter as the great engineering bodies are bound by the detailed provisions of their respective constitutions. Each, however, met the situation in an admirable spirit, and the committee was duly appointed. The several societies appointed distinguished members who were in touch with the educational movements of the day, a number being past presidents of their respective Societies.

After eighteen months had been used in organizing the committee, a number of meetings were held and the work before it was canvassed. The actual work began with a study of the catalogues of the various engineering schools from which it was found after two attempts, to be impossible to obtain the desired information. The American Society of Civil Engineers then made an appropriation to see if the study could be carried farther with profit, but it was again found to be utterly impracticable to obtain an adequate idea of the accomplishments and purposes of engineering schools from their catalogues. The committee thereupon invited the Carnegie Foundation for the Advancement of Teaching to undertake an investigation which it was estimated would cost ten thousand dollars. It seemed necessary that properly equipped agents should visit the engineering schools throughout the land, and after investigating these, should study the relations between the engineering schools and the engineering professions. At that time the Carnegie Foundation for the Advancement of Teaching was engaged upon a study of medical education, and was hardly in a position to incur the necessary

expense for this one. Fortunately Mr. Carnegie came to the rescue by increasing the endowment and the Foundation has now taken up the study and appointed an agent. The agent appointed, Dr. C. R. Mann, is not an engineer, but he was trained in physics, a closely allied subject. It is expected that he will make a full and complete investigation and draw up an analytical report.

As the committee's work has progressed we find that there is greater unity of ideals and fewer fundamental differences of opinion than appeared to exist at the time of our first meetings. We are optimistic with respect to the ultimate outcome of the work of this committee. Eventually we hope to have a report which will be of great value to the cause of engineering education.

GARDNER C. ANTHONY,
CHARLES L. CRANDALL,
DUGALD C. JACKSON,
S. P. E. E., Representatives on the Joint Committee on Engineering Education.

PRINTED ENGINEERING RESOURCES.

BY J. MARTIN TELLEEN,

Assistant Professor of English, Case School of Applied Sciences.

The university has been defined as a collection of books. Similarly, the engineering college may be defined as an arrangement of laboratories. The requirement imposed upon the university library is that it be rich in the archives of the past as well as in the modern contributions to the literature of the several departments of the university: the books must constitute a good working library for the university. The requirement imposed upon the engineering laboratory is that it be ample to demonstrate modern methods and practice: in fact, some college catalogues announce that the equipment of their several laboratories is *modern and up-to-date.*

That an engineering college must be modern, that all its equipment should be kept up-to-date is self-evident. Old apparatus representing discarded methods is thrown on the junk heap. The textbooks are based, supposedly, upon the principles of the latest discoveries and invention, but, we are told, when the text of a new engineering book is still in the hands of the printer, technical journals are informing us of improved methods exemplified by recent successful practice. This occasional insufficiency of textbooks is further indicated by the use of catalogues and other trade publications as textbooks in a few courses.

These facts, however, do not prove that engineering books are useless or that our engineering colleges are not in need of libraries. Such conclusions would be preposterous. The fact is that with the tremendous activity in every branch of engineering together with the constantly increasing specialization within each branch there is a greater need than ever of the printed engineering resources. This need has been met by the establishment of excellent working libraries for engineers.

Our colleges are striving to gather an ample collection of books, but they often find themselves outdistanced by local engineering societies, by public and private municipal libraries, and even by manufacturing concerns.

The purpose of this paper is, first, to sketch broadly some of the important accumulations of engineering books, pamphlets, periodicals, and other printed matter, and, secondly, to indicate the nature of the work these libraries are doing. The reader must bear in mind that all the important engineering libraries have not been included and that the figures here given are not absolutely correct or taken on a certain uniform date.* The facts here recorded, it is hoped, are sufficient for the purpose just stated—to indicate the rich printed resources available to engineers.

The libraries which contain these accumulations are both public and private. They are the national and municipal libraries and the libraries of our colleges, of national and local engineering societies, and of manufacturing concerns. The last mentioned class is exceedingly important and probably constitutes our most specialized collections. To give the complete list is impossible, but some idea may be had by considering the list taken from *Special Libraries*, Vol. 3, No. 8, Oct. 1912: Stone and Webster, Boston; Public Service Corporation, Newark; United Gas Improvement Company, Philadelphia; H. M. Byllesby and Company, Chicago; Commonwealth Edison Company, Chicago; Toronto Gas and Electric Light Company, Toronto; People's Light, Gas, and Coke Company, Chicago; American Telephone and Telegraph Company, New York; Boston Consolidated Gas Company, Boston; New England Telephone and Telegraph Company, Boston; The General Electric Company, Schenectady; The Studebaker Corporation, South Bend; National Carbon Company, Cleveland; Diamond Rubber Company, Akron; Goodrich Rubber Company, Akron; Bausch and Lomb Optical Company, Rochester; American Brass Company, Waterbury; and Dodge Manufac-

* Unless otherwise specified, the date of the given figures is April, 1914.

turing Company, Mishawaka, Indiana. The ideal of such a library was expressed by a prominent engineer when in a recent address he said that industrial laboratories "should each one be developed around a special library, the business of which should be to collect, compile, and classify in a way to make instantly available every scrap of information bearing upon the materials, methods, products, and requirements of the industry concerned."

Of the cities which have become prominent library centers Washington is, of course, preëminent on account of its being the location of the Library of Congress, the largest library in the country and the depository of every book copyrighted in the United States. The extent and nature of its resources can be determined by virtue of its classified catalogue printed in two volumes in 1869 and since that date on cards, which, fortunately, is found available for consultation in some one prominent library of the leading cities throughout the United States. Other libraries in Washington which may be of service to engineers in some particular are the National Museum and the libraries of the United States Coast and Geodetic Survey, United States Weather Bureau, United States Department of Agriculture, United States Geological Survey, United States Surgeon-General, and the United States War Department. This list has been taken from *Special Collections in the Libraries in the United States,* Bulletin 1912, No. 23, United States Bureau of Education, an exceedingly valuable compilation.

The importance of New York City is due primarily to the fact that it is the location of the headquarters of the several national engineering societies and as such holds the libraries of these organizations. The library of the American Society of Civil Engineers has a collection of more than 80,000 books, pamphlets, and maps, and receives regularly 350 periodicals and society publications. It has a collection of more than 7,000 specifications and is especially strong in historical material relating to railways and waterways, municipal reports,

and material on the geology of the United States. Its catalogue was published in 1900 and 1902.

The library of the engineering societies contains the libraries of the American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the American Institute of Mining Engineers. It has 65,000 volumes and receives 806 current magazines. It reports a valuable collection on electricity and magnetism and a strong collection of works on machinery and appliances for handling and conveying materials of all kinds. In 1913 the library published its *List of Periodical Sets* and is now coöperating with the New York Public Library, The Chemists' Club, The American Society of Civil Engineers, Columbia University, and Stevens Institute in preparing a union list of periodicals.

The library of the Chemists' Club contains 18,000 volumes, not counting valuable duplicates, and about 400 sets of periodicals. Three years ago it received the library of The American Chemical Society. It is at present the largest chemical library in America.

These three libraries on account of their large accumulation of books, their proximity to each other, the constant coöperation among themselves, and their willingness to serve resident and non-resident engineers, establish New York City as the library headquarters of American engineers. To supplement the resources of these libraries the city has its public library with 60,000 volumes pertaining to technology, and the libraries of Columbia University, Brooklyn Polytechnic Institute, Pratt Institute, and Cooper's Institute.

The city of Boston has its public library, the libraries of Harvard University and Massachusetts Institute of Technology (95,528 volumes—December, 1913), the library of the Engineers' Club (7,500 books, 2,000 pamphlets), and several valuable private engineering libraries, of which the most prominent is that of Stone and Webster (about 6,000 books, pamphlets, and technical journals). These and other library resources of Boston were made especially available by the organ-

ization in 1912 of the Boston Coöperative Information Bureau, "a voluntary association of persons and organizations for mutual assistance in the ascertainment of sources and supplies (generally local) of information, whether these exist in written or printed form, or simply as mental equipment, and whether rendered available by purchase, or by loan or gift." Its officers include the librarians of the important libraries of the city. The Bureau maintains a central catalogue and has in its employ two inter-library workers. Boston is also the headquarters of the Special Libraries Association, which has for its object "to promote the interests of the commercial, industrial, technical, civic, municipal, and legislative reference libraries, the special departments of public libraries, universities, welfare associations, and business organizations."

Pittsburgh with its Carnegie Library probably represents the American city that is best serving the community in the field of technology. Its library comprises about 60,000 volumes on technology, of which 39,213 are in the technology reference collection. It receives more than 400 scientific, technical, and trade journals, of which 260 are included in a card index covering the period from 1906 to date; receives about 100 "house organs"; and has a collection of more than 6,000 trade catalogues, which are made accessible by means of card indexes arranged by both author and subject. In addition to its monthly bulletin it has issued several important bibliographies on engineering subjects, the latest of which is on "Smoke and Smoke Prevention," an extensive annotated bibliography of 164 pages, compiled by the Mellon Institute of the University of Pittsburgh.

The city of Chicago is rapidly assuming preëminence among the technical libraries of the country by virtue of the John Crerar Library. When we consider that this library was first opened to the public on April 1, 1897 with only 15,000 volumes ready for use and 7,000 more in the hands of the cataloguers, and that its total endowment of more than three and one half million dollars is devoted to the establishment of "a free

public reference library of scientific and technical literature," we realize the present importance and the future possibilities of the city of Chicago in the field of engineering literature. At the beginning of this year this library reported 17,461 volumes, 2,294 pamphlets, and 230 current periodicals classified under engineering. Electrical engineering, however, is included under the subject of physics, and in the field of physics the library has 7,648 volumes, 1,396 pamphlets, and 68 periodicals. Chemical engineering is classified under chemical technology and the resources in this field about equal those in physics. In accordance with an agreement with the John Crerar Library, the Chicago Public Library limits its purchases of engineering books to the more popular books. The site of the proposed John Crerar Library building adjoins that of the Public Library. One other local library deserving of mention is that of the Western Society of Engineers with its 15,000 volumes dealing mostly with local engineering subjects.

In other cities are found interesting and valuable libraries. Philadelphia has the library of the Franklin Institute with its extensive collection of engineering periodicals and patent office reports and the Wm. B. Stephens Memorial Library, Manayunk, " a reference library for scientific, historical, and technical instruction and research which would meet the needs of a rising industrial community." New Bedford boasts of a complete collection of literature pertaining to the textile industries. Providence is known as having an excellent college library in engineering. A further enumeration of notable libraries is unnecessary, as this paper does not attempt to cover the field exhaustively.

The service which these libraries are performing is of both a popular and a technical nature. Most of them serve the resident and the non-resident. The popular service of the public libraries in providing the artisan with the more or less popular treatises on engineering need not here be considered. Our interest is in the service that these libraries are rendering the engineering student and the practicing engineer.

In the first place, most of these libraries print information in regard to their collections. Several are printing bulletins, some of which are annotated with valuable criticism of the new additions to the library. Franklin Institute, Pratt Institute, and the public libraries of New York, Pittsburgh, and Cleveland issue such pamphlets. The publication of technical bibliographies is not general. Several bibliographies of importance to engineers have been issued by the Carnegie Library of Pittsburgh, New York Public Library, and the John Crerar Library. The latter library has issued a list of bibliographies on special subjects and is now engaged in preparing a bibliography on the history of useful arts, including, of course, engineering. The Public Library of Cleveland coöperates with the local engineering society by preparing a short bibliography on the subject of the paper to be presented, which list is printed on the reverse side of the announcement card of the meeting. Printed volumes containing the catalogues of our engineering libraries are few and out of date. Two cards catalogues of exceptional value are those of the Library of Congress and the John Crerar Library. The service which card catalogues can perform is indicated by the fact that the card catalogue of the latter library is deposited at Armour Institute of Technology, Chicago Public Library, Field Museum of Natural History, University of Chicago—all within the city of Chicago—as well as in several other American libraries and in at least one foreign library. This same library has a union catalogue, which contains cards from the Library of Congress, Harvard University, Royal Library of Berlin, Royal Library at The Hague, and the libraries of the Universities of Illinois and Michigan.

Most of the libraries are prepared to make investigations for the resident and the non-resident engineer. The library of the American Society of Civil Engineers has already prepared more than 700 bibliographies and that of the engineering societies has compiled some 500 reference lists. The libraries of engineering societies, the American Society of Civil Engineers,

and the Chemists' Club, are especially well equipped to prepare bibliographies and to make reprints of any article that they may have on file. A very low charge is made for such service. The extent of this service on the part of the several libraries is indicated in the following statement issued by the Chemists' Club: "Information on any chemical subject that has been investigated and put into print can now be supplied at reasonable cost to busy professional men, technical publications, lawyers, patent attorneys, manufacturers, and teachers. On short notice articles will be copied, translations made, bibliographies prepared, and searches of chemical or patent literature carried on, both in the Chemists' Club Library and in the principal libraries of New York City. The world's work in chemistry is thus made available to all."

As periodical literature is of special value to engineers, it is imperative that our libraries be especially strong in this dedepartment. The unusually large number of technical periodicals is apparent by considering the two printed lists: "List of Technical Indexes and Bibliographies Appearing Serially," *Monthly Bulletin of the Carnegie Library of Pittsburgh*, June, 1910, and "Class Catalogue of Current Serial Digests and Indexes of the Literature of Pure and Applied Science," Library Association, London, 1912. As is apparent from the titles, these two lists do not record all engineering periodicals, but only those containing bibliographies. A complete list of engineering periodicals does not exist. Two libraries have printed a list of the periodicals that they receive: the Franklin Institute published its in 1912 and the library of the Engineering Societies in 1913. The Boston Public Library issued in 1907 a union list of periodicals, a list that is now being brought up to date. As was previously stated, several of the libraries of New York are preparing a similar list. The union lists which are being prepared in these two metropolitan centers will reveal their resources in engineering periodical literature and incidentally emphasize the possibility of more effective coöperation.

The reference departments of these libraries contain not only the most important of the engineering bibliographical indexes as the *Engineering Index* and the *Industrial Arts Index,* but a wealth of handbooks, yearbooks, lexicons, atlases, encyclopedias, biographical dictionaries, membership lists of engineering societies, directories, and other publications of value to the student and the engineer. As these collections keep the engineer in touch with present conditions and practice, the directors of our libraries have in most cases given special attention to the reference departments. Their importance to the engineer is indicated by the following excerpt from the *Engineering News* of November 23, 1911, in its account of the establishment of the excellent reference library at Brown University: "If any criticism at all were to be made of Mr. Corthell's gift, it would be that such a library as has been collected is needed a thousand times more for use by practicing engineers than it is by teachers and students in engineering colleges."

In addition to collecting periodical literature and important engineering books as they come from the press, some of these libraries are specializing in certain directions. As a result they are becoming depositories of rare and valuable books bearing on the development of a particular subject. In some of the libraries are found the collections made by certain prominent scientists. The Special Collections in Libraries in the United States mentions some of these special libraries. For instance, the following collections on electricity are found: the Latimer Clark in the Engineering Societies Library, the Dr. Gustav Wiedermann in the John Crerar Library, and the Park Benjamin in the United States Naval Academy. Some of these may today be only of an historic value, but, nevertheless, as such they prove invaluable to those engaged in research work. In commenting on the collection of the historical engineering publications owned by the engineering societies, the librarian concludes with the following statement: "The early work of the engineer is represented by many valuable works dating back to the beginning of the printing of scientific books,

and the many volumes in Latin and mediaeval English form a nucleus of what, it is hoped, may in the future be a valuable source of information for the American engineer interested in the history of his profession."

The application of this discussion to the membership of the Society for the Promotion of Engineering Education is undoubtedly self-evident. An engineering college is in need of a good working library, the number and nature of its periodicals and books depending primarily on the curriculum of the college. In addition to having such a library for ready and constant use, the college should provide the student with instruction in the use of library facilities and with definite information in regard to the leading engineering libraries of the country, their particular strength, and their willingness to aid a student in his research work and an engineer in solving his practical problem. The impelling argument in favor of acquainting the graduating student with the rich accumulations of our printed engineering resources is that these libraries are in a sense post-graduate schools in engineering.

ENGINEERING EXTENSION WORK AT THE UNIVERSITY OF KANSAS.

BY P. F. WALKER,

Dean of the School of Engineering, University of Kansas.

University extension work is coming rapidly to the front as an important feature of educational work throughout the country, especially in the states of the middle west and west. Under the leadership of Wisconsin, many of the state universities are taking up the work with great activity. In the development of this work there has been much discussion as to the possibilities of giving it a character which should entitle it to credit comparable to that given for work in residence, thus counting toward the usual degree awarded at graduation. In the engineering branches in particular this question is one which is rather difficult of solution and it has seemed wise in most cases to follow a conservative policy in the matter.

At the University of Kansas the work has developed mainly along the established channels and there are included the many usual forms of activities through which the influence of the university is being extended throughout the state. These include such means as the lecture bureau, the municipal reference bureau, and package libraries, in addition to the regular work of instruction by correspondence.

All this work is administered through the central office of the extension division although the bulk of actual work of instruction is taken care of by members of the various departments of the established schools of the university. The school of engineering is offering a limited number of the courses which can be handled most readily by the correspondence method, it being customary to vary the work to suit the needs and abilities of individual students. A few of these subjects may be taken for credit toward the degree, but a large proportion are offered under names corresponding to those given regularly in

residence, but not for credit when the work is done entirely by correspondence. Many courses are being offered in which the work is of a character much more elementary than that included in those which carry credit, most of them being listed under a subhead of vocational courses. These are for the benefit of boys and young men who have not had the necessary preparation for entrance to any university or college but who might profit by study in connection with their daily work. The university, acting under the state laws, and with the express sanction of the state legislature, is affording these facilities for home study in a manner which brings but a nominal expense to the student. This expense is but a small fraction of that required for similar work with the established correspondence schools, the idea being that in this manner the benefit of legislative appropriations for the maintenance of the institutions for higher education may be extended to a larger number of the citizens of the state.

During the past year there has gone into effect in the engineering department of the A. T. & S. F. Ry. a new rule which requires that men taken on to the staff in permanent positions must be graduates from an engineering course in a school of established reputation. In that department there were many young men who had come up from the ranks, many of them without any education beyond that secured in the high school, and others who have spent from one to three years in various universities. On the request of these men an investigation was begun for the purpose of determining the conditions under which many of them might be enabled to take up student work by the extension method, while at the same time they could hold their positions and maintain their earning capacities on the road. The arrangement was finally made whereby the officials of the road agreed to recognize the men who should enter upon the work and the question of how best to make provision for it came before the school of engineering.

In accordance with this plan classes have been started at two division points on the railroad. The first of these is at To-

peka, where the offices of the engineer of the eastern lines are located, as well as the office of one of the larger divisions, thus concentrating a large number of engineering employees. Several of these men have been students at the university for varying periods, and are now enrolled for work under the regular correspondence system in such subjects as geology and "Engines and Boilers" which are offered for credit. The purpose is to keep these men engaged in work of this character until the others have been given work in mathematics and the fundamental sciences, and made ready to enter classes in the more advanced engineering subjects.

In dealing with the men of this latter class who have had no work beyond that of high school, classes have been organized with an instructor who goes from the university to the meeting place most convenient to the student. At Topeka, classes in algebra, plane surveying and physics are now being held, and at Newton, which is the division point next to Topeka on the west, classes in algebra and plane surveying are organized. The instructor is a member of the regular engineering staff of the university and the work given is the same as that given in the regular resident classes. The practice is being followed, however, of requiring each of these men to make out the regular assignment papers which would be used if the work were being done by the correspondence method, thereby making it possible for them to continue in the work in case the class should be given up or the individual member be sent to another point on the road.

As indicated above, as soon as these men have secured the foundation training in mathematics necessary for the advanced work, they will be grouped with those who have already had this work in residence at the university, and classes thus formed in mechanics, hydraulics, railway surveying, railway location, and other engineering subjects will be conducted.

In this manner it is expected that a large portion of the work required for the degree in civil engineering will be given while the men are engaged in the daily routine of their work

for the railroad. Many of the subjects cannot be given thus, however, especially those which require time to be put in either in the laboratory or the designing room. In many cases the textbook work of a course may be given in the detached class and the laboratory portion given at some time when the student may find it possible to come to the university for a period of study. The only particular requirement which has been imposed by the faculty of the school of engineering is that every student before being graduated must spend the equivalent of at least one year in residence. During this period much of the laboratory and special drawing courses may be grouped. As already noted, many of the men directly concerned at the present time have already had much more than this one year of resident study to their credit, and in such cases the fulfilling of the requirements for completing laboratory and design courses will be the only conditions imposed.

This plan as it has been worked out with these men employed in the engineering department of the Santa Fe Railroad particularly in mind, has points of interest and value beyond the individual cases involved. One element of interest which attaches to the plan is that it provides for a true extension of the teaching function of the university to men who are directly employed in commercial work. From the educational viewpoint alone this will afford an opportunity for interesting study, coördination of practice work with theoretical instruction being here provided for in a manner very different from that which is usually attempted in connection with established schools. Close attention will be given to the way in which the men develop under this method of instruction. A great deal of earnestness and steadfastness will be exercised by those who pass through this course of study with success, which course will, of necessity, be extended through a period considerably longer than the regular four years. Field practice secured in the course of their routine work should stand them in good stead in connection with such subjects for study as railway surveying and railway location. In a limited way, credit

for work thus done, may be substituted for that usually done under the school instructors.

A second point may be noted, with especial reference to the general question of extension instruction work. It is generally accepted that the most successful extension work is done through the establishment of so-called "centers." The special classes which have been organized in connection with this engineering work form ideal nuclei for extension centers. It may be predicted that work thus laid out, having in view a definite accomplishment by the students, like that of graduation, will prove to be more effective and to have a much more lasting place in the scheme of education through the public institution, than will work of a miscellaneous character enrolled for by individuals either scattered through a state or concentrated in a group in some municipal center. Valuable as the entire system of instruction through the extension method may be, the opinion may be expressed that the results which will best merit the expenditure of effort and university funds will be those accompanying a definitely organized and administered line of study, giving some specific and reasonably complete course of training.

It may be further noted that this same idea has been followed by the University of Kansas in laying out vocational extension courses for those boys and young men who are not fitted to do the regular engineering work. To each prospective student there is presented the idea of entering upon a brief course of study including several different but related subjects, the completion of which is calculated to have the effect of preparing him for a more successful accomplishment of the work of his trade or calling.

FIRST AND SECOND LAWS OF THERMODYNAMICS.

BY S. L. BROWN,

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"Heat is energy," and "heat will not flow up hill" are sayings that may express the substance of the two generalizations of thermodynamics, but it is very difficult to explain the content and application of these two laws to heat phenomena in a way which will appeal to the student or person who is unfamiliar with thermodynamics. Some mechanical analogies may be made which are valuable in the presentation of this phase of the physical sciences, but great care must be exercised or erroneous analogies will be drawn. The first law may be disposed of in a few sentences, but the importance and field of application of the second law can only be shown by a careful consideration of the physical phenomena and arbitrary definitions which apply to the transformation of heat energy into mechanical energy or vice versa. The following pages are intended to give an explanation of these two laws, and of the phenomena which are fundamentally associated with the second law, in such a way that the uninitiated may easily understand them.

First Law of Thermodynamics.

When mechanical work is done on a body, its temperature may rise and the mechanical energy be transformed into heat energy. That is, the body has gained something which is equivalent to the expended mechanical work, and which is called heat. To show that the body which is heated does gain something that is equivalent to the mechanical energy expended in producing the rise of the temperature, the following experiment might be performed. Place a paddle stirrer in 1,000 grams of water, carefully guard against any loss of heat to

surrounding bodies and measure the amount of work, W, expended in turning the stirrer, necessary to raise the temperature of the water from 20° C. to 21° C. Pour this water into 500 grams of water at 18° C. and the resulting temperature of the mixture is 20° C. Expend the same amount of work W by means of the stirrer on 500 grams of water at 18° C. and the final temperature is 20° C. That is, the 1,000 grams of water by returning to its initial condition will produce the same effect on 500 grams of water at 18° C. as the work W will produce if applied directly to the 500 grams of water at 18° C. Therefore, the 1,000 grams of water while being heated by the dissipation of the work W stored something which is equivalent to the work, and which is called heat.

Careful experiments have been performed to determine accurately the work required to heat water through definite temperature ranges. The results of Rowland's experiments show that the work required to raise the temperature of a given mass of water 1° C. is not the same for all temperatures. About one per cent. less work is required to raise a given mass of water from 30° C. to 31° C. than is required to raise the same amount of water from 0° C. to 1° C.

Reversible and Irreversible Processes.

If the maximum amount of useful energy is to be obtained from a quantity of water at a particular level by lowering it to a new level, the lowering must be done by a water motor which will allow the least amount of turbulence. If the maximum amount of useful energy is to be obtained from a given quantity of heat, a heat engine must be used which will allow the least amount of turbulence while receiving the heat at a particular temperature, converting some of the heat energy into useful work, and giving out the remainder as heat to a low-temperature condenser. When water flows freely to a lower level, or when heat flows freely to a lower temperature, no useful energy is obtained, and only turbulence results. If a water motor, while converting the potential energy of a

waterfall into mechanical energy, or if a heat engine, while converting heat energy into mechanical energy, allows any turbulence, only a fraction of the available energy is converted into useful work, and the remainder can be described as dissipated. Turbulence, consisting of whirls, surges, waves, heat conduction, wire drawing, etc., must be avoided in order that motors and heat engines may have their highest efficiency.

A peculiar feature of a turbulent condition, when once initiated, is that it gradually approaches a state of quiescence or equilibrium, and cannot be arrested at any point in its sweep short of the final equilibrium.

Simple Sweeps.—A bucketful of water may be dropped from a height into the still water in a reservoir below, and turbulence, consisting of splashes, waves (including sound waves), etc., is produced. The turbulent state, however, finally subsides, and the water in the reservoir is still again. This kind of settling to equilibrium is called a simple sweep. A hot piece of metal may be thrown into a vessel of cold water and a turbulent state produced. The metal and water finally settle to the same temperature, and in so doing, perform a simple sweep.

Trailing Sweeps.—Allow water to flow down the side of a hill; at any position on the hill the water is attempting to come to rest at that level, but the slope of the hill keeps up the turbulence and the water never catches up with the quiescent state which it is trying to reach as long as it is flowing down the hill. The external influence, the height of the hill, is continually changing; and, therefore, the state of turbulence trails behind the continually changing state of equilibrium which it is trying to reach.

Place a Bunsen burner under a vessel of water; the water inside the vessel attempts to come to the temperature of the warmer vessel, but it never catches up with the quiescent state which it is trying to reach so long as the temperature of the vessel is rising. The external influence, the temperature of

the vessel, is continually changing; and therefore the state of turbulence trails behind the changing state of equilibrium.

The steam in a cylinder may be kept from settling to a quiescent state by the moving piston increasing or decreasing the pressure. At any instant the steam is trying to settle to equilibrium, but it never catches up with the varying conditions produced by the moving piston. Sweeps of the above kind are called trailing sweeps.

Steady Sweeps.—When water flows continually from a height into a reservoir below, the energy of the falling water produces turbulence which tends to settle to a state of equilibrium, but, since the water continues to flow from above, a steady state of turbulence or a steady sweep is produced.

When heat flows from a region of constant high temperature inside a furnace to a region of constant low temperature outside the furnace walls, a steady turbulent condition results; or when steam flows from a region of constant high pressure to a region of constant low pressure a steady sweep is produced.

Any one of the above sweeps is accompanied by a dissipation of energy; that is, a sweep reduces the amount of energy that is available for useful work. The total energy available from a waterfall or from a difference in temperature may be divided into useful work obtained by a water motor or a heat engine, and energy dissipated by sweeps.

Reversible Processes.—If the bucket of a water motor is filled without turbulence, slowly lowered and emptied without turbulence, no sweeps are produced, no energy dissipated, and the motor has its maximum efficiency. This ideal procedure could be stopped and reversed at any point. That is, the bucket, when half way down, might be sent back and emptied at the upper level by an infinitesimal external effort; and the motor is described as reversible. A gas during slow heating or slow compression is passing through a series of states of equilibrium, and hence a very small change in external influences will reverse either of the processes. It is evident that a reversible process results only from ideal conditions, which can

be approached but never attained in practice; nevertheless, the conception of such an ideal process is valuable in the consideration of actual processes, as will be seen from what follows.

Irreversible Processes.—All processes involving sweeps are irreversible. The turbulence caused by filling the bucket of a water motor, by allowing the water to fall into the bucket from a slightly higher level cannot be stopped and while stopping, lift the water back to the higher level. Heat will flow to a lower temperature region from a higher, but a small change in external influences will not reverse the flow of heat. A gas will flow to a region of lower pressures from a higher, but a small change in external influences will not reverse the direction of flow. Since a turbulent condition cannot be stopped short of a limiting state, processes involving sweeps cannot be reversed.

Nothing irreparable has happened during a reversible process, but there is a certain havoc wrought during an irreversible process which is irreparable. Sweeping, or irreversible processes, diminish the useful work which could have been obtained from a given amount of heat energy.

The Reversible or Carnot Cycle of an Ideal Heat Engine.

Fig. 1 is the indicator diagram of an ideal engine receiving W_1 units of heat energy at a temperature T_1, liberating W_2 units of heat energy at a temperature T_2 and thereby doing $W_1 - W_2$ units of work. The cycle of this engine may be divided into four parts: (1) a slow isothermal expansion of the working substance (a gas for example), (2) a slow adiabatic expansion of the gas until the lower temperature is reached, (3) a slow isothermal compression of the gas, and (4) a slow adiabatic compression of the gas until the higher temperature is reached. A detailed description of the cycle would be as follows: (1) The gas slowly expands and does work on a piston while receiving heat at a higher temperature. The work done during this part of the cycle is represented by

the area $ABFH$, and the gas changes from volume and pressure P_1V_1 to P_2V_2 without changing its temperature. (2) The heat supply is then cut off, and the gas slowly expands from the condition P_2V_2 to P_3V_3, while the temperature drops from T_1 to T_2. The work done during this part of the cycle is rep-

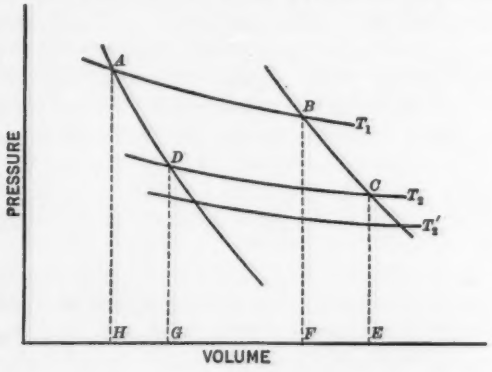

FIG. 1.

resented by the area $BCEF$, and this work must come from the energy of the gas, since the expansion is adiabatic. (3) The gas is then slowly compressed and work is done on it by the piston while the gas gives out heat at the lower temperature. The work done on the gas during this part of the cycle is represented by the area $CEGD$, and the gas changes from the condition P_3V_3 to P_4V_4 without changing its temperature. (4) The giving out of heat is then arrested and the gas is slowly compressed from the condition P_4V_4 to P_1V_1 while the temperature rises from T_2 to T_1. The work done on the gas during this compression is represented by the area $DGHA$, and this work is the increase of energy in the gas, since the compression is adiabatic. Each repetition of this cycle* will do the work represented by the area $ABCD$ by the use of an

* It is necessary to base this argument on a complete cycle to insure that the working substance has neither gained nor lost energy.

equivalent amount of heat energy. No turbulence is involved in this cycle, since the heat is supposed to be absorbed and given out at the respective temperatures without a temperature gradient and the expansions and compressions are made very slowly. This is the very best that a heat engine can do while working between the prescribed temperatures, and its efficiency is

$$E = \frac{W_1 - W_2}{W_1}. \qquad (1)$$

THE KELVIN OR WORK SCALE FOR MEASURING TEMPERATURES.

When an ideal engine, as described above, converts half the heat energy that it receives into useful work and reconverts the other half into heat again, the temperature of the condenser is half the temperature of the source from which the engine is receiving heat energy; or, if an ideal engine converts into useful work one tenth of the heat energy received and reconverts the other nine tenths into heat again, the condenser is nine tenths as hot as the source on the Kelvin or thermodynamic scale. Therefore, the heat received and the heat ejected by an ideal heat engine are proportional to the temperatures of the heat source and the heat-sink on the thermodynamic scale, and the temperature of a sink which would permit an ideal engine to convert into useful work all the heat energy it receives would be called absolute zero.

Thermodynamic regeneration and degeneration. Assume that when a heat engine receives heat at a high temperature, all the heat energy is transformed into mechanical energy. This transformation from heat to mechanical energy is called regeneration, and we shall let W_1/T_1 (total energy received divided by the temperature on the work scale) measure the regeneration.

When the engine allows any of the energy which it has received to be dissipated into non-useful forms, there is said to be degeneration. Degeneration may result from the engine converting some energy into heat at the temperature of the

sink, or it may result from sweeping processes, or from both. Using the same measure of degeneration as was used for regeneration, W_2/T_2 is the degeneration resulting from the engine converting W_2 units of energy into heat at the temperature T_2; and, if the engine is reversible, this is all the degeneration. According to our work scale for measuring temperatures,

$$\frac{W_1}{W_2} = \frac{T_1}{T_2} \tag{2}$$

or

$$\frac{W_1}{T_1} = \frac{W_2}{T_2} \tag{3}$$

when there is no degeneration by sweeps. That is, the degeneration equals the regeneration when all the processes of the engine, while converting into work a portion of the heat energy which it has received, are reversible. The engine is then working most efficiently between the temperatures T_1 and T_2, and its efficiency, according to the first law of thermodynamics and conditions which permit equation (3), is

$$E = \frac{W_1 - W_2}{W_1} = \frac{T_1 - T_2}{T_1}. \tag{4}$$

What is the efficiency of an ideal heat engine when working between the temperature of steam from water boiling under a pressure of one atmosphere and the temperature of melting ice under the same pressure? When the variations of volume and pressure of a gas (hydrogen or air, for example) with temperature as measured on any thermometer (for example a constant-pressure gas thermometer) are known, and the change of temperature produced by free expansion of the gas is known, it is possible to find the energy W_s received by an ideal heat engine at the temperature T_s and the energy W_i given out at a temperature T_i while the engine is converting $W_s - W_i$ units of heat energy into mechanical energy.

When the gas expands isothermally while receiving the heat energy,

$$W_2 = \int_{p_1}^{p_2} p \cdot dv + \int_{p_1}^{p_2} de_1/dp \cdot dp, \qquad (5)$$

where $\int_{p_1}^{p_2} p \cdot dv$ is the work done by the gas while expanding from p_1v_1 to p_2v_2 (see Fig. 1) at the temperature T_2, and $\int_{p_1}^{p_2} de_1/dp \cdot dp$ is the corresponding change in the internal energy of the gas, de_1/dp being the rate at which the internal energy of the gas is changing with pressure at the temperature T_2.

When the gas is compressed isothermally, while giving out heat energy,

$$W_1 = \int_{p_3}^{p_4} p \cdot dv + \int_{p_3}^{p_4} de_2/dp \cdot dp, \qquad (6)$$

where $\int_{p_3}^{p_4} p \cdot dv$ is the work done on the gas while being compressed from p_3v_3 to p_4v_4 at the temperature T_1, and $\int_{p_3}^{p_4} de_2/dp \cdot dp$ is the corresponding change in the internal energy of the gas, de_2/dp being the rate at which the internal energy of the gas is changing with pressure at the temperature T_1.

From the results of the Joule and Thomson porous plug experiment, the changes in the internal energy of a gas can be determined and the second integrals in equations (5) and (6) evaluated. The accurate determination of the relation between pressure and volume at constant temperature permits the first integrals of equations (5) and (6) to be evaluated. Professor Callender's results* show

$$W_2/W_1 = 1.3663 \qquad (7)$$

and therefore,

$$T_2/T_1 = 1.3663 \qquad (8)$$

by definition of temperature ratio on the work scale.

* Professor H. L. Callender, *Phil. Mag.*, 1903, Vol. 5.

Arbitrarily divide the temperature interval between ice and steam temperatures into 100 degrees.

Solving equations (7) and (8)

$$T_s - T_i = 100 \text{ degrees}, \tag{9}$$

$$T_s = 373.1 \text{ degrees}, \tag{10}$$

and

$$T_i = 273.1 \text{ degrees}. \tag{11}$$

Using the value of the ratio of the two temperatures, or the values of the two temperatures as found above, the efficiency of the ideal engine is,

$$E = \frac{T_s - T_i}{T_s} = .268 \text{ or } 26.8 \text{ per cent}. \tag{12}$$

Since the change in internal energy of a gas is small, and since the relation between pressure p, volume v, and absolute temperature t (on the gas scale) can be approximately expressed by $pv = Rt$, equations (5) and (6) give

$$W_1 = Rt_1 \log p_1/p_2, \tag{13}$$

$$W_2 = Rt_2 \log p_4/p_3. \tag{14}$$

The relation between temperature and pressure when a gas expands adiabatically is,

$$\frac{t^\gamma}{p^{\gamma-1}} = k \text{ (constant)}, \tag{15}$$

where γ is the ratio of specific heats of the gas. Therefore,

$$\frac{t_1^\gamma}{p_2^{\gamma-1}} = \frac{t_2^\gamma}{p_3^{\gamma-1}} \tag{16}$$

and

$$\frac{t_2^\gamma}{p_4^{\gamma-1}} = \frac{t_1^\gamma}{p_1^{\gamma-1}} \tag{17}$$

or

$$\frac{p_1}{p_2} = \frac{p_4}{p_3}.$$

This relation between the pressures and equations (13) and (14) gives

$$\frac{W_1}{W_2} = \frac{t_1}{t_2} = \frac{T_1}{T_2}, \tag{18}$$

which shows that temperatures measured on the gas scale and thermodynamic scale are the same when the small corrections mentioned above are neglected. The gas temperature scale is so nearly equal to the thermodynamic scale, that it suffices for all practical measurements.

The Irreversible Cycle of a Heat Engine.

When a heat engine permits sweeps of any kind while receiving heat at a temperature T_1 and giving it out at a temperature T_2, there is more degeneration than is represented by W_2/T_2, where W_2 is the heat energy that an ideal engine would liberate at the lower temperature. The energy represented by the sweeps might be furnished by a reversible engine taking w_1 units of energy at the higher temperature T_1 and giving out w_2 units at the lower temperature T_2. The energy represented by the turbulence is $w_1 - w_2$, and the degeneration is w_2/T_2. Therefore, the total degeneration when the engine is working irreversibly is

$$\frac{W_2}{T_2} + \frac{w_2}{T_2}. \tag{19}$$

The regeneration w_1/T_1 required to furnish the energy for the sweeps is included in the W_1/T_1, and hence the regeneration is not changed by sweeps but remains W_1/T_1. The result is, when the engine is working irreversibly, that the degeneration exceeds the regeneration;

$$\frac{W_1}{T_1} < \frac{W_2 + w_2}{T_2} \tag{20}$$

and the efficiency of the engine is

$$E = \frac{W_1 - W_2 - (w_1 - w_2)}{W_1} \tag{21}$$

$$= \frac{T_1 - T_2}{T_1}\left\{1 - \left(\frac{w_1 - w_2}{W_1 - W_2}\right)\right\}, \qquad (22)$$

since $W_1/T_1 = W_2/T_2$ and $w_1/T_1 = w_2/T_2$. The fraction $(w_1 - w_2)/(W_1 - W_2)$ measures the deviation from the ideal reversible working of the engine; or, in other words, the deviation from maximum efficiency depends on the fractional part of the energy, possible to extract from the working substance, that is dissipated by sweeps.

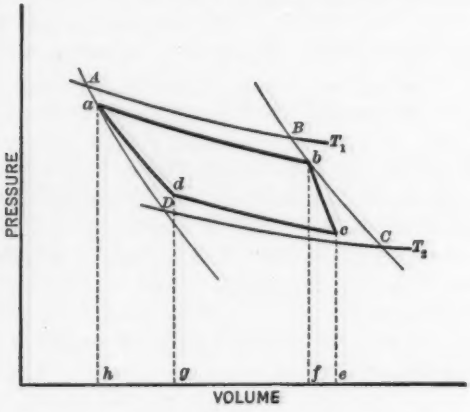

FIG. 2.

Fig. 2 is the indicator diagram of an engine receiving W_1 units of heat energy at a temperature T_1 and doing less than $W_1 - W_2$ units of work, where W_2 is the heat energy that an ideal engine would liberate at a temperature T_2 when it received W_1 units at the higher temperature T_1. The cycle of this engine may be divided into four parts: (1) rapid expansion of the working substance (a gas for example), (2) cooling of the gas while rapidly expanding and losing heat by radiation, conduction, etc., after the heat supply is cut off, (3) rapid compression of the gas while giving out heat at a lower temperature and (4) heating of the gas while being

rapidly compressed and losing heat by radiation, conduction, etc., after being cut off from the refrigerating source. A detailed description of the cycle would be: (1) the gas rapidly expands and does work on a piston while receiving heat from a heat source at a higher temperature than the expanding gas. The work done during this part of the cycle is represented by the area *abfh*, and the gas changes from volume and pressure p_1v_1 to p_2v_2 while its temperature falls. (2) The heat supply is then cut off and the gas expands from the condition p_2v_2 to p_3v_3 while the temperature falls. The work done during this part of the cycle is represented by the area *bcef*, but since there is degeneration by radiation, etc., the energy lost by the gas exceeds the work represented by the area *bcef*. (3) The gas is then rapidly compressed, and work is done on it by the piston while the gas gives out heat to a refrigerator which is at a lower temperature than the gas. The work done on the gas during this part of the cycle is represented by the area *cegd*, and the gas changes from the condition p_3v_3 to p_4v_4 while its temperature rises. (4) The refrigerating source is then cut off, and the gas is rapidly compressed from p_4v_4 to p_1v_1 while the temperature rises to the original temperature of the gas. The work done on the gas during this part of the cycle is represented by the area *dgha*, but since there is degeneration by radiation, etc., the work done on the gas exceeds the energy it gains.

Each repetition of this cycle will do the work represented by the area *abcd*. A reversible engine, taking the same amount of heat at the temperature T_1 and giving out heat at a temperature T_2, would have done the work represented by the area *ABCD*. This irreversible engine has done only area *abcd*/area *ABCD* as much work as a reversible engine would have done. That is, area *ABCD* minus the area *abcd* represents the energy used by sweeps, or

$$\frac{\text{area } ABCD - \text{area } abcd}{\text{area } ABCD}$$

is the fractional part of the heat energy which is dissipated by

the irreversible processes involved: namely the turbulence produced by rapid expansion and compression, by the heat conduction while the gas is receiving heat from a source at a higher temperature source and giving it out to a refrigerator at a lower temperature, and by radiation and conduction to surrounding bodies at any time during the cycle. The fraction $(w_1 - w_2)/(W_1 - W_2)$ in equation (22) is equal to

$$\frac{\text{area } ABCD - \text{area } abcd}{\text{area } ABCD}$$

and the efficiency of this irreversible engine is

$$E = \frac{T_1 - T_2}{T_1}\left\{1 - \left(\frac{\text{area } ABCD - \text{area } abcd}{\text{area } ABCD}\right)\right\} \quad (23)$$

$$= \frac{T_1 - T_2}{T_1} \cdot \frac{\text{area } abcd}{\text{area } ABCD}. \quad (24)$$

The relative amount of work obtained by a real engine as compared to the amount obtained by an ideal engine for the same amount of heat energy used may be called the sub-thermal efficiency of the real engine; and therefore, the thermodynamical or thermal efficiency of an engine is the thermodynamical efficiency of an ideal engine, working between the same temperatures, multiplied by its sub-thermal efficiency.

Since the temperatures of available refrigerating sources are far above the absolute zero, thermodynamical efficiencies must be small. The thermodynamical efficiency of an ideal engine working between 200° C. (473° absolute) and 70° C. (343° absolute) is about 27.9 per cent.; and hence an engine which has a sub-thermal efficiency of 40 per cent. would have a thermodynamical efficiency of 11.16 per cent. while receiving heat from steam at 200° C. and giving it out to a condenser at 70° C.

The Second Law of Thermodynamics.

Thermodynamic degeneration cannot be repaired without energy compensation, nor can heat be made to flow from region

of low temperature to one of high temperature without such compensation.

The degeneration produced by an ideal heat engine while doing the work represented by the area *ABCD* of the indicator diagram in Fig. 1 cannot be repaired except by the expenditure of at least as much energy as is represented by the area *ABCD*. If the working substance of an ideal engine receives heat from the refrigerator while slowly expanding as represented by the isothermal T_2 in Fig. 1, adiabatically contracts until the higher temperature is reached, isothermally contracts while giving out heat at the higher temperature, and then adiabatically expands until the original volume, pressure and temperature are reached, the repair uses only as much energy (represented by the area *ABCD*) as was obtained when the degeneration was produced by a reversible engine; but if the transference of heat from the lower to the higher temperature involves turbulence of any kind, the repair uses more energy than was obtained when the same amount of heat was used by a reversible engine.

If heat is made to flow from a low to a high temperature region, at least as much work must be expended as would be obtained by an ideal engine when it uses the same amount of heat with the same difference in temperature. If the forcing of the heat from the low to the high temperature region involves sweeps of any kind, an additional amount of work must be expended to supply the energy represented by the turbulence.

Another statement of the second law might be, that work cannot be obtained by cooling a body below the lowest available refrigerator temperature; but this expression is really included in the latter part of the statement above. Consider T_2 to be the lowest available refrigerator temperature, and an attempt made to obtain work by cooling a body to a lower temperature T_2' (see Fig. 1). The additional work gained by the reversible engine, working between T_1 and T_2' instead of between T_1 and T_2, is represented by the area *DCC'D'*, but the energy required to make the heat flow from the tempera-

ture T_2' to the higher temperature T_2 would at least equal the work represented by the area $DCC'D'$. If the engine does not work reversibly in the district from T_2 to T_2', or if the forcing of the heat from the temperature T_2' to the higher temperature T_2 involves sweeps of any kind, the additional amount of work obtained by cooling the working substance below the lowest available refrigerator temperature would be less than the work required to force the heat from T_2' to the higher temperature T_2.

Entropy.

The value of a waterfall for the production of mechanical energy depends on the amount of water furnished by the fall and the height of the fall. Consider a stream that consists of a number of waterfalls, and whose physical state is changed by having water taken from (or added to) it. This change in the physical state of the stream depends upon how much water is taken from it, and at what level the water is taken. A given mass of water taken from the stream above the last fall in the water's course will cause a small change in the stream's potency as compared to the change that would be produced by taking the same mass of water from the stream above its first fall. From the foregoing articles, it is evident that the value of the heat in a body for the production of mechanical energy depends upon how much heat is extracted from it, and the temperature at which the heat is extracted as compared to the available condenser or refrigerator temperature. If it were possible to lower the water which is taken from a waterfall to the center of the earth, all of the potential energy of the water might be converted into mechanical energy (by a perfect water motor); and likewise, if a refrigerator at a temperature of absolute zero were available, all the energy of the heat which is extracted from a hot substance might be converted into mechanical energy (by an ideal engine). The physical state of a substance, or its change of state as involved with the above two thermodynamic features is termed the entropy or change in entropy of the substance. When a body absorbs a

quantity of heat Q at an absolute temperature T, a change in the physical state of the substance is produced, and the change is described by saying that its entropy has been increased by Q/T; or, when Q units of heat are extracted from a body at a temperature T, its entropy is said to be decreased by Q/T. The regeneration in the cycle of an ideal heat engine is, therefore, the decrease in the entropy of the substance from which the engine is receiving heat and the increase in the entropy of the working substance of the heat engine. Likewise, the degeneration in the cycle of an ideal heat engine is the increase in the entropy of the refrigerator and the decrease in the entropy of the working substance.

It can be proved that, when a substance changes from one physical state (designated by its density and temperature, for example) to another, the change in its entropy is the same for all reversible paths which lead from one state to the other.* For example, a gas may reversibly change from 76 centimeters pressure, zero C. temperature to 100 centimeters pressure, 100° C. temperature by being adiabatically compressed until the temperature reaches 100° C., and then isothermally expanded until the pressure is 100 centimeters; or, the gas may be adiabatically compressed until its temperature is 50° C., then isothermally expanded to a lower pressure, then adiabatically compressed until the temperature is 100° C., and then isothermally expanded until the pressure is 100 centimeters; and, in either case, the change in the entropy of the gas is the same if all the changes are reversible. Since a substance neither gains nor loses heat energy during adiabatic changes, no change of entropy can result from the adiabatic changes. Therefore, the change of entropy during the isothermal expansion at 100° C. for the first described path from original to final state in the above example, is the sum of the changes of entropy at 50° C. and 100° C. for the second described path. The entropy of a substance is generally expressed for unit mass of the substance referred to some standard state. The

* See Preston's "Theory of Heat" (translated by Cotter), Sec. III.

entropy of a substance or unit mass of a substance can best be determined by considering the change of entropy in getting from the particular state to the standard state by a path consisting of two parts; one part of the path being along an adiabatic which leads from the state in question to the isothermal of the standard temperature, and the other part being along this isothermal. The change of entropy as the adiabatic change is made is zero, and hence the entropy of the substance is the heat extracted (or absorbed) while the substance is isothermally changing to the standard state, divided by the temperature of the standard state.

Since the regeneration is equal to the degeneration for a reversible engine, the change in the entropy of a substance when carried through a reversible cycle is zero. When a quantity of heat Q flows from a hotter (absolute temperature T_1) portion of a body to a cooler (absolute temperature T_2) portion, the entropy of the body is increased by $Q/T_2 - Q/T_1$. Any irreversible process incurs more degeneration than regeneration, and hence any irreversible process causes an increase of entropy. Since reversible processes cause no change of entropy and irreversible processes cause an increase, the result of all the processes of the universe must be a continually increasing entropy.* Entropy may be expressed in any energy unit per degree absolute on any temperature scale.

* A very interesting and instructive article, which compares the continually increasing entropy to our sense of time as a steady flux, is written by W. S. Franklin in *Physical Review*, June, 1910.

ELECTRICAL ENGINEERING LABORATORY INSTRUCTION.

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One of the principal objects of the teaching of electrical engineering laboratory is that of inspiring the students with the importance of development along lines of initiative, application and analysis. With the proper choice of work and under proper conditions the laboratory offers an ideal opportunity for intellectual development. It should be our duty as laboratory instructors, to teach the students to think and to apply intelligently such knowledge of theories as they may have to the study and operation of the various types of apparatus.

For several years the method of conducting electrical laboratory work at Tufts College was to lay out a certain number of tests to be performed with more or less elaborate directions as to the method of procedure for carrying them out. Often these tests did not have any direct relation to each other in the order in which they were to be done. While we realized that this was not ideal we were forced to such methods largely from lack of the necessary apparatus to do the work otherwise.

Our experience seems to show that, without considerable effort on the part of the instructor, the student when given definite directions lacks initiative in his work and only takes a more or less perfunctory interest in it. To relieve this condition the whole scheme of teaching the dynamo section of the laboratory work was changed. In the three years that we have conducted the work under the new conditions a marked increase in interest on the part of the student has been noted and we feel that a greater return in educational value is being obtained.

Under the old conditions the machinery was mostly perma-

nently set up, as shown in Fig. 1, so that the student had but little to do with the selection and arrangement of his apparatus although he had considerable wiring to do. It was felt that a greater interest in the work would be obtained if the student could select and arrange his apparatus to his own taste without instruction or direction from the instructor as to the methods of his procedure.

FIG. 1.

At the beginning of the laboratory period a brief time is devoted to a discussion of the test to be undertaken in which the points in theory connected with it are indicated so that the student may know clearly what the object of his work may be. In the laboratory he is told what machinery is available and it then becomes his duty to find and assemble it in any space not

otherwise occupied. This gives him practice in judging capacities of machinery necessary for his test and arranging his entire apparatus to the best advantage. The instructor usually comments upon improper choices after the student is ready to start his observational work. It is done at this time largely as a means of impressing the point more firmly in the student's mind, as a change then means a certain amount of work on his part. Our experience has been that the student seems more interested in his work when there is a certain amount of manual labor connected with it in such a way as to offer him that freedom which no permanently set up apparatus will permit.

When he has set up his machinery he then has to make complete wiring of all his apparatus without aid from the instructor. Our custom is to ask the student if he has properly protected his apparatus with circuit breakers when he asks if his wiring is correctly done. We say to let the circuit breakers judge of the accuracy of the wiring. "Fool proof" motor starters are used and an ample supply of circuit breakers for the student's use is provided. Circuit breaker protection is also made on all the main switchboard circuits so that no material damage can result from improper wiring. The instructor rarely looks over the wiring or comments upon it before the student throws on the power. If the circuit breakers open when the student tries to start up his apparatus it is left entirely with him to find and remedy his own troubles. We find that this method, while it may use considerable time in the laboratory period, is of much importance in that it tends to develop certain powers in the man that he should have at his command.

The student soon finds that he is given work to do and that it is largely "up to him" to produce the desired results in a reasonable time by such means as he can muster. He also learns that if the results do not turn out well that the work has to be repeated. The instructor usually is not in the room with the student while he is doing his work although he is always available for consultation. Our experience shows us

that the student feels more free to experiment with his apparatus if he knows that the instructor is not watching his every move. We make it a point, however, to be present when the student throws on the power in order to make such criticisms as may be needed if the apparatus does not operate properly. If the student after a reasonable time cannot find or remedy such difficulties as may arise the instructor will try by such questioning as may be needed to draw out the required information from the student rather than tell him directly, thus encouraging his powers of analysis.

Where our old scheme provided for definite tests of a more or less correlated nature our new method considers the work to be done in the nature of "studies." Thus in our direct current laboratory we take up the study of the d.c. shunt generator, the study of the d.c. shunt motor, etc. In the alternating current work we consider the study of the alternator, the study of the induction motor, the study of the transformer, etc. The idea in so considering the work is to gather data by such tests as may be found necessary to make a complete study of the theoretical and practical operation of the particular type of apparatus under study. Where possible, such methods as are applied in the regular commercial testing laboratories are used. This serves to interest the student in the methods he uses since he feels that if he is following the so-called practical methods he is doing something worth while. At the same time he gathers all the data necessary for the theoretical work needed.

For reports we used to require rather complete accounts of apparatus, methods, etc., but we now confine our attention largely to neatly tabulated data on specially ruled sheets, such curves as may be required, a very brief statement of the methods used and a complete discussion of the interpretation of data. We lay our greatest emphasis upon the interpretation of data obtained for we believe that herein lies one of the greatest educational values of the laboratory work. As an engineer the student will not have much to do with operating, hence,

methods become of secondary importance. He must, however, be able to size up a situation, whether it be one of executive nature or one dealing with equipment. In the latter case all that he will usually have to base his judgment upon will be certain data or curves. Unless he has been trained along such lines of work as to develop his analytical powers he will lack ability which as an engineer he ought to possess.

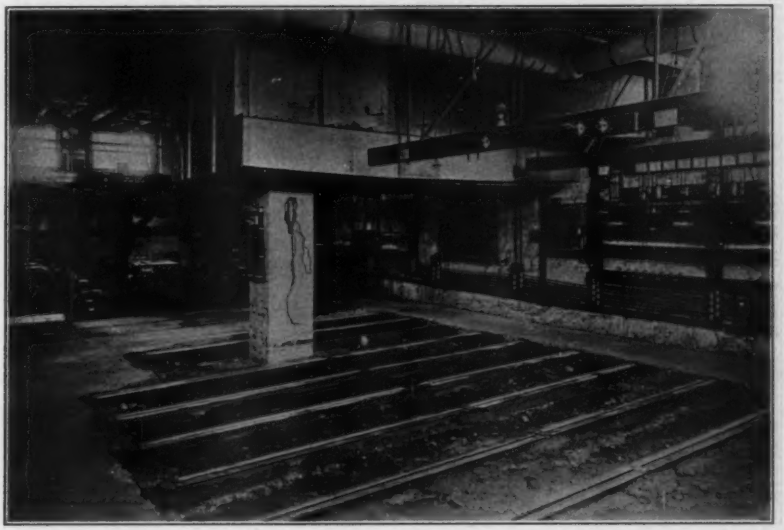

FIG. 2.

When the student has gathered sufficient experimental data and plotted curves in his study of a piece of apparatus he is given a list of things which may be determined from a study of the data. When this has been worked out a general discussion of the test, including methods and interpreted results, is taken up under the direction of the instructor. The reports are not passed in for inspection until the completion of the study of the particular piece of apparatus used. While

this may seem to give the student an opportunity to get behind in his work we find that it has not made any noticeable difference from the conditions when we required the notes to be checked each day. Owing to the continual use of the data and curves in intercomparison of results from the several tests, it is essential that the student shall have all the information always with him and that unless he keeps his work up

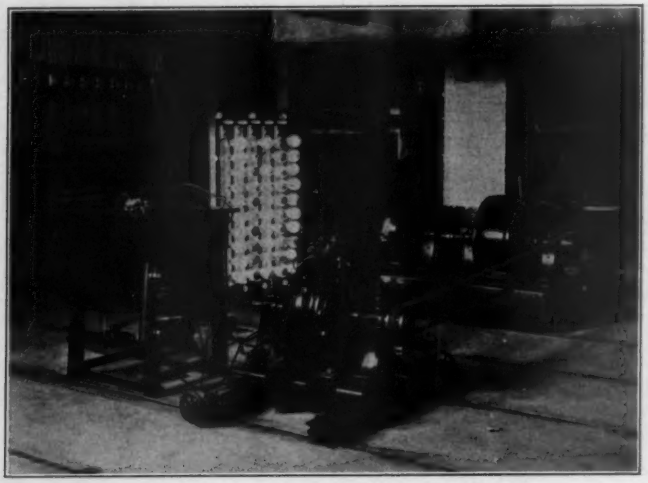

FIG. 3.

to date he cannot work out the things required in the several tests.

We require a reasonable degree of accuracy in the taking of observations, otherwise we cannot use the values in the several sets of data for comparative checks. The student is made to repeat any work that will not give the checks necessary and thus soon finds that "slip-shod" methods will not pass. This tends toward developing care and accuracy in the work.

When we first tried out this method we found at once that

our former arrangement of machinery could not be used so we dismantled one half of our laboratory and inserted I-beams in the floor giving us when completed a slotted floor to which the machinery could be bolted in any position desired. These I-beams, as may be seen in Fig. 2, are put down in sections with removable wooden blocks between so that bolts can be slipped into the slots with which to fasten special clamps to the rails holding the machines. In order to facilitate the handling of the machinery we found that the use of short lengths of double I-beams as rails, provided with hand wheels for the adjustment of the machines when belt driven, gave very good service; the machines being bolted to the beam rails so as to give the maximum rigidity to the mount. This is clearly shown in the mounting of the generator in Fig. 3.

A trial of this arrangement of floor and machine mounting proved to us that it was vastly superior to our old method and gave great flexibilitiy to the use of our equipment. The change in the floor was accomplished at a comparatively small expense and so we have just had the other half of the dynamo room floor fixed with the channel iron, as seen in Fig. 2, which shows the method of placing the beams before the cement filling is put in.

Our machinery is now stored in the corners or around in any space available and is dragged out in position and set up as needed. This gives us plenty of room for our squads to work in without interference with each other or with other machinery. A squad usually consists of three men which gives each man plenty of the work to do. Fig. 3 shows a set up of apparatus for test in the space occupied by most of the machinery shown in Fig. 1 and indicates the great freedom of space for work that we now have over the congested conditions shown in Fig. 1.